THE ELEMENTS OF RADIO TRANSMISSION AND RECEPTION

Lesson No. ND-4

SPRAYBERRY ACADEMY of RADIO

ESTABLISHED 1932

PUEBLO, COLORADO

THE ELEMENTS OF RADIO TRANSMISSION AND RECEPTION

LESSON ND-1

So far in your study of the S.A.R. course you have covered some of the basic fundamentals of electricity and radio. You should now have a good general understanding of the nature of electricity and the way it acts in performing work or expending energy. Without hesitation you should now be able to tell anyone who asks you the meaning of **volts, current, resistance, power, direct current, alternating current, magnetic lines of force,** etc. If it should happen that you don't have this clear understanding, stop now and go back over the previous lessons you have already studied to refresh your memory. There is no point to your attempting to go further up the ladder of radio knowledge at this time unless you have a good understanding of what you have already covered. This is good sound advice and you should not hesitate to apply it if you feel that it is necessary.

In this lesson you are going to **get a preview of some of the practical applications of magnetic and electric lines of force.** In presenting these principles, new subjects will be introduced, concerning which complete and detailed explanations cannot be given. If that were attempted, the length of this lesson would defeat the objectives we want to accomplish. **So remember as you study this lesson that this is a broad outline only.** It will be left to other lessons to present a detailed study of such things as microphones, vacuum tubes, etc. **The prime purpose of the lesson is to give you a broad outline of how radio signals are transmitted and received. Please keep this idea in mind as you study through the lesson.**

CBS Photo

Ted Husing, famous sports announcer, makes an on-the-spot broadcast by remote pick-up method.

The two essential elements of a radio broadcasting system with which you are most familiar are no doubt the microphone at the studio of the radio station and the speaker of the radio set in the home. What occurs in between these two elements is accomplished by a complex system of electrical circuits, including all that makes up modern radio.

Our entire course of training is devoted to this subject. We shall not attempt at this time to go into all of the ramifications of transmitters, but an outline comprehensive enough in scope will be given you to get a general understanding of what takes place. With this background you can then proceed to take up the study of component radio parts and circuits in later lessons with a general idea of just what you are trying to accomplish in your studies.

The Start of the Radio Signal

There are two principal methods employed to start a radio signal on its way to the receiver. The first method is called a "remote pick-up." This method requires that an operator take a microphone and small amplifier to a location away from the studio or transmitter. He then sets up his equipment and connects it to a telephone line provided by the telephone company. The signals picked up by the microphone are then fed over the telephone line to the transmitter, which in turn radiates the signal in the form of a radio wave. If a telephone line is not available at the remote location the operator will use a small portable transmitter of low power output. A receiver at the transmitter location will in turn be used to pick up the signal from the portable transmitter. This receiver will amplify or make the signal stronger before it is fed to the main transmitter.

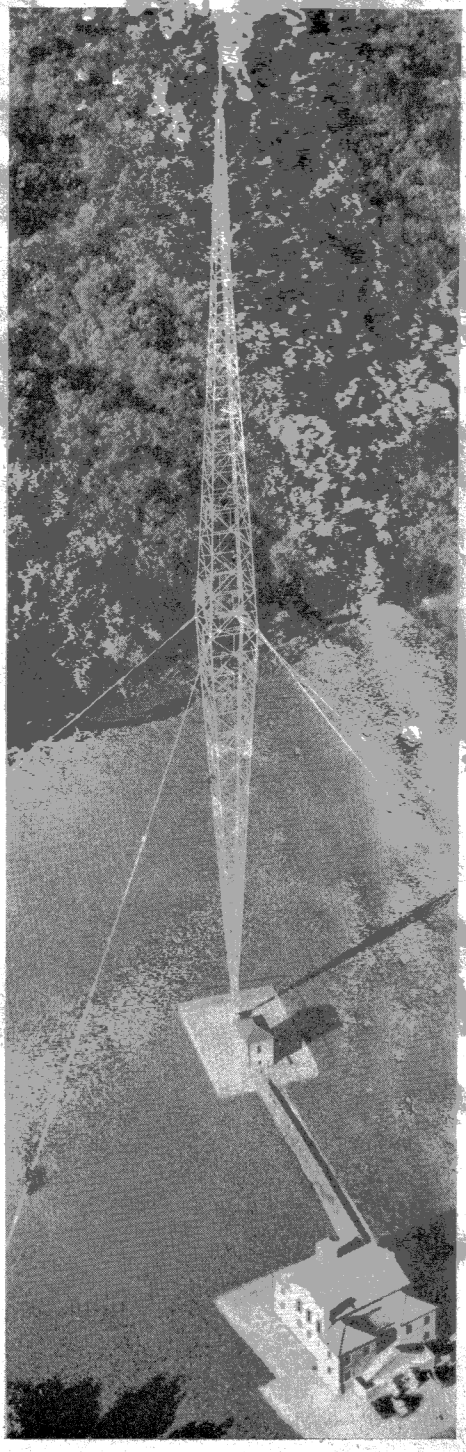
The second method of picking up a signal is at the studio of the station. At this point signals are picked up by the microphone, as at the remote location. What happens next depends on the actual location of the transmitter. If it is in the same building as the studio then the output of the microphone is fed directly into the input of the transmitter. On the other hand, the modern trend is for the station to use a downtown location for the studio, whereas the transmitter may be several miles away on the outskirts of the town. In this case a small preamplifier is used at the studio to strengthen the signals from the output of the microphone. The output of this preamplifier is then fed to a telephone line which connects the studio with the transmitter. At the terminals of the telephone line at the transmitter another small preamplifier may be used before the signal is finally fed to the transmitter proper.

Another method of generating a signal not involving the use of a microphone is often employed. This involves the use of wax or composition records. Such a record is often called a transcription. By whatever name it may be known, in essence a signal is generated through the use of a needle following the record groove. This needle, following the record variations, is caused to move a coil of wire in a magnetic field which in turn generates a voltage corresponding to the signal variations. Another method permits the generation of a signal by means of electrostatic lines of force. Still another signal generating method is by means of an intense light, a photo-electric cell and film for sound reproduction. The well-known **sound track** along the edge of motion picture film utilizes this signal producing method.

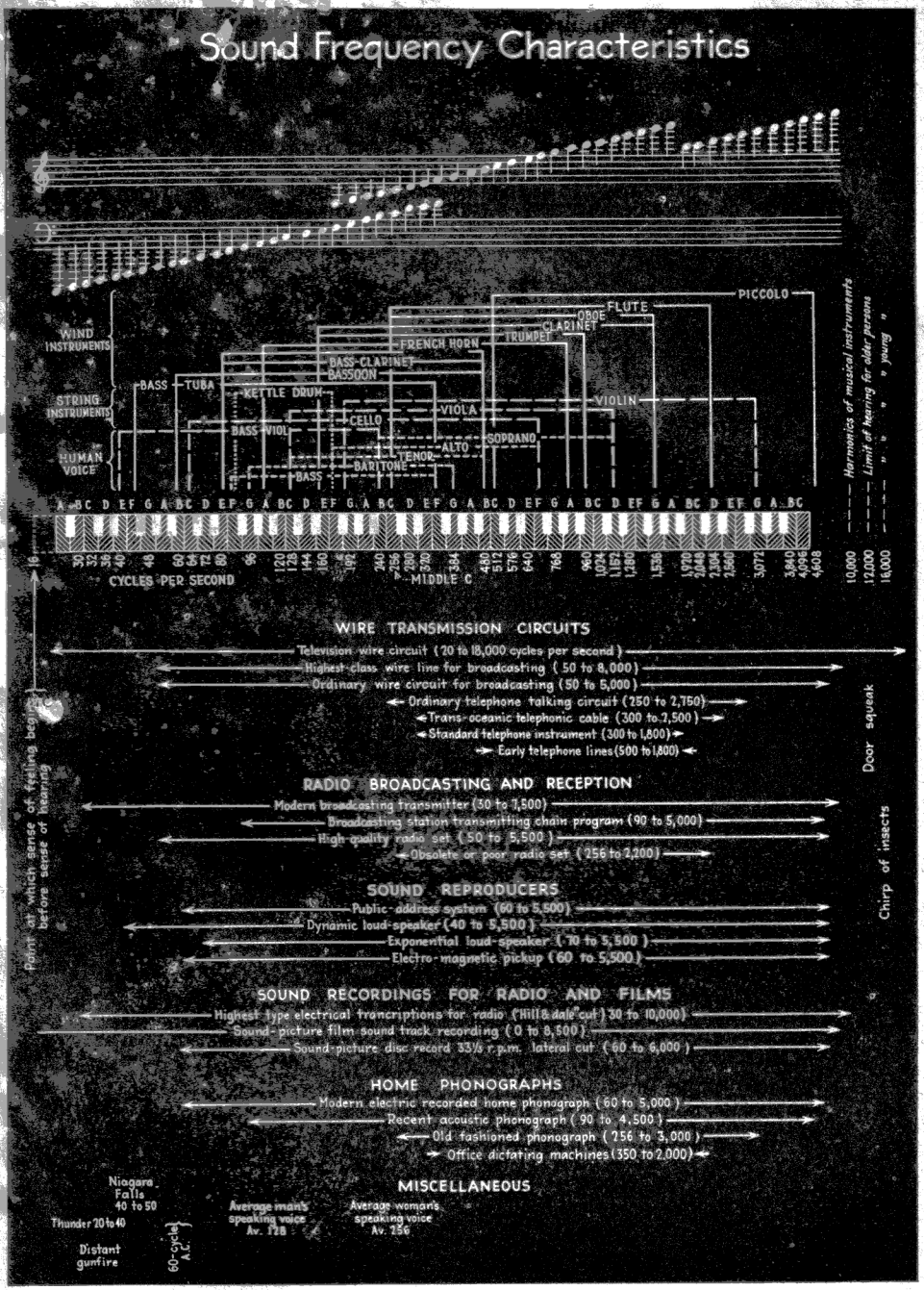
FREQUENCY RANGE OF AUDIO SIGNALS

The foregoing brief explanation of pickup of a signal by different methods makes no attempt to give you the technical details—that is left to later lessons where the individual subjects may be given adequate treatment. All that we want you to understand at this time is that these methods of generating or picking up a signal are available to feed the signal to the transmitter. All that remains to complete this general picture is to correctly identify such a signal. It is properly called an **audio signal** because in the form of sound energy it is audible and may be heard by the human ear. Such a signal may also be referred to as a voice signal, speech signal, sound signal, etc. In general the extreme frequency range for such a signal is from about 20 cycles on up to about 18,000 cycles per second. Few people indeed can recognize signals at these extreme limits. Most people hear best between 200 and 3000 cycles, although their range of hearing is not, of course, limited to such a narrow band of frequencies. It is interesting to note in passing that many microphones and speakers cut off frequencies sharply above 5000 cycles and below 50 cycles. You will get technical explanations of these principles later on in other lessons.

One important point about all of this is that the signals of the microphone at the transmitter and at the receiver speaker should be exactly the same and of the same frequency range. Remember that this type of



Transmitters are often located out in open country miles from the glamorous studios, as is the case with Columbia's WABC (right).


Sound Frequency Characteristics
WIND INSTRUMENTS
STRING INSTRUMENTS
HUMAN VOICE
BASS
TUBA
KETTLE DRUM
BASS VIOL
CELLO
BASS-CLARINET
BASSOON
FRENCH HORN
TRUMPET
OBOE
CLARINET
FLUTE
PICCOLO
VIOLA
VIOLIN
ALTO
TENOR
BARITONE
SOPRANO
BASS
A B C D E F G A B C D E F G A B C D E F G A B C D E F G A B C D E F G A B C D E F G A B C
CYCLES PER SECOND
MIDDLE C
Harmonics of musical instruments
Limit of hearing for older persons
" " " young "
WIRE TRANSMISSION CIRCUITS
Television wire circuit (20 to 18,000 cycles per second)
Highest-class wire line for broadcasting (50 to 8,000)
Ordinary wire circuit for broadcasting (50 to 5,000)
Ordinary telephone talking circuit (250 to 2,750)
Trans-oceanic telephonic cable (300 to 2,500)
Standard telephone instrument (300 to 1,800)
Early telephone lines (500 to 1,800)
RADIO BROADCASTING AND RECEPTION
Modern broadcasting transmitter (30 to 7,500)
Broadcasting station transmitting chain program (90 to 5,000)
High-quality radio set (50 to 5,500)
Obsolete or poor radio set (256 to 2,200)
SOUND REPRODUCERS
Public-address system (60 to 5,500)
Dynamic loud-speaker (40 to 5,500)
Exponential loud-speaker (70 to 5,500)
Electro-magnetic pickup (60 to 5,500)
SOUND RECORDINGS FOR RADIO AND FILMS
Highest type electrical trancriptions for radio (Hill & dale cut) 30 to 10,000)
Sound-picture film sound track recording (0 to 8,500)
Sound-picture disc record 33⅓ r.p.m. lateral cut (60 to 6,000)
HOME PHONOGRAPHS
Modern electric recorded home phonograph (60 to 5,000)
Recent acoustic phonograph (90 to 4,500)
Old fashioned phonograph (256 to 3,000)
Office dictating machines (350 to 2,000)
MISCELLANEOUS
Niagara Falls 40 to 50
Thunder 20 to 40
Distant gunfire
60-cycle A.C.
Average man's speaking voice Av. 128
Average woman's speaking voice Av. 256
Door squeak
Chirp of insects
Point at which sense of feeling begins before sense of hearing

Courtesy Electronics

Although we are accustomed to thinking of the tone range (audio frequencies) of pianos and other musical instruments as being very wide, they are actually extremely limited, covering only from about 20 to 10,000 cycles. The human hearing range goes up to about 18,000 cycles, but is insignificant compared to radio frequencies which operate up to the astounding figure of 1,000,000,000 cycles!

signal is known as an **audio signal** of low frequency. If this is kept clearly in mind it will help you to understand the complete radio wave better.

The accompanying chart will give you a pictorial idea of audio or sound frequencies. Study this chart carefully for it contains much interesting information. It mentions new subjects which have not been introduced in this or previous lessons. These new subjects will be brought up later on at the proper point where adequate explanation can be given. The main point you should check on this chart is the frequency limit of different musical instruments and that of the different types of electrical circuits. The numbers on the chart refer to the frequency in **cycles per second.** You will remember that you studied frequency and cycles in a previous lesson. If their meaning is not clear to you at this time, you should review the subject.

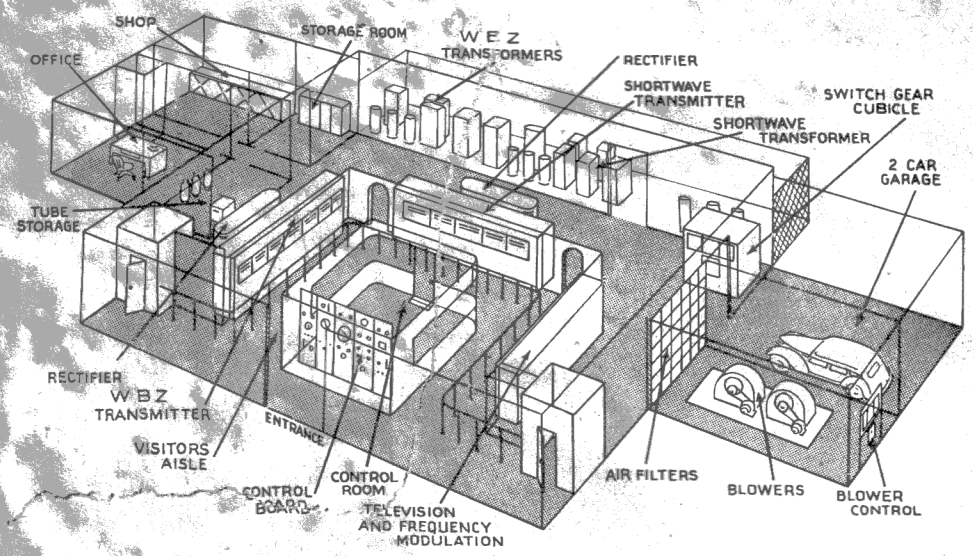
You should now have a clear understanding of the meaning of sound frequencies and of their lower and upper limits. The next step is to get these translated into the form of a radio wave which may be radiated to any point on the face of the earth. **It is at this point that conditions change abruptly.** This is because low value audio frequencies will not travel any appreciable distance in the form of a magnetic wave.

You will remember in your study of magnetism it was shown that the amount of voltage induced in a conductor depended on the **rate of change** of the magnetic lines of force or on the number of turns of wire through which the magnetic lines of force could be made to sweep. An ordinary receiving antenna is usually just one or two wires or at most a few turns of wire. Assuming that magnetic impulses varying at the rate of sound frequencies could sweep through a receiving antenna it follows that little or no signal voltage would be induced because the **rate of change** is relatively slow because of the low frequencies involved. Furthermore it is characteristic of magnetic lines of force (or magnetic waves) that the lower the frequency the less the distance they will travel. From this it is easy to see that some means must be adopted to **effectively increase the frequency** (make the magnetic lines change faster) if the original sound frequencies are to be radiated to any point on the face of the earth. This is actually accomplished through the transmitter process. This process will be explained in greater detail further on in this lesson. Before going on with that, however, you should learn more about the broad band of frequencies in radio.

THE FREQUENCY SPECTRUM

The word **spectrum** can refer to the order of progression in anything. Thus the order of numbers from 1 to 10 or from 50 to 100 is a spectrum of numbers. Likewise the order of frequency progression from a lower to a higher value is a **frequency spectrum.**

The broad scientific definition for low frequencies is **sonic frequencies.** However radio men are more accustomed to referring to **audio frequencies** or AF, meaning those frequencies lying between 20 and 18,000 cycles. This no doubt suggests to you that there are other frequency bands below 20



Typical of modern, well laid out broadcasting stations is WBZ's 50,000 watt transmitter at Hull, Massachusetts, across the harbor from Boston, and shown in cut away drawing above.

cycles and above 18,000 cycles and that is exactly correct. Those frequencies lying below 20 cycles in the spectrum are often referred to as **subsonic.**

Those frequencies above 18,000 cycles on up to 100,000 cycles are often referred to as **supersonic.** These frequencies are used for commercial and governmental activities.

Above 100,000 cycles on up to 1,600,000 cycles the term **radio frequency** or RF is used to describe this band of frequencies. From 100,000 to 550,000 cycles various sea and air navigational aids are in use along with other commercial and government services.

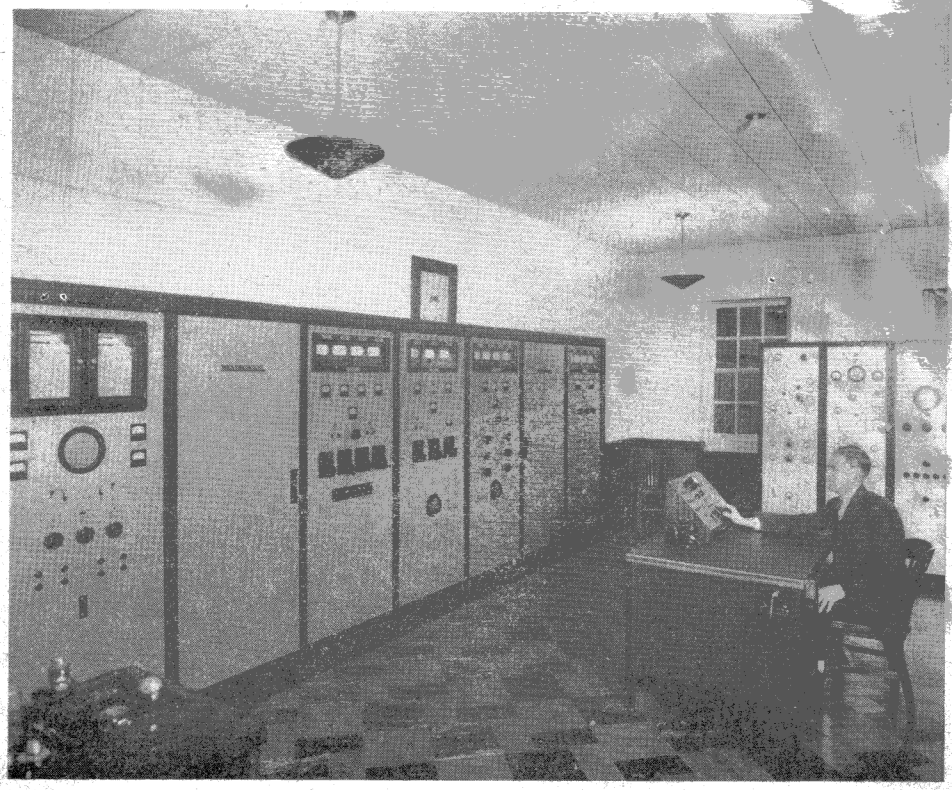
From 550,000 to 1,600,000 cycles the well known broadcast radio stations operate. This is known as the broadcast band. Radio stations are spaced 10,000 cycles apart on this band and each division is known as a channel. This gives 105 channels in the broadcast spectrum which must be shared by well over 900 radio stations. The Federal Communications Commission has control over the allotment of frequencies to the various radio stations. They have worked out a system of allocating stations and frequency sharing which is a model for the whole world. By careful control and cooperation with other world governments we have a well regulated broadcast system with a minimum of interference. Without this control and regulation there would be so much interference between radio stations that few stations could be heard satisfactorily.

When dealing with frequencies above 100,000 cycles the numbers become large and cumbersome. Thus an abbreviated system is used wherein the frequency is stated in terms of 1000 cycles. Instead of using the word cycles, **kilocycles** is used. Thus one kilocycle is equal to 1000 cycles and to state 100,000 cycles in terms of

kilocycles it is written and spoken as 100 kilocycles. 1,000,000 cycles would be 1000 kilocycles and 1,600,000 cycles would be 1600 kilocycles. The word kilocycle is also rather long so instead of using it the abbreviation **KC** is used. To change a frequency value given in cycles to an equivalent kilocycle value, multiply by .001. Thus 780,000 cycles equals 780 kilocycles. To change a kilocycle value to an equivalent cycle value multiply by 1000. Thus 1150 KC equals 1,150,000 cycles.

Above 1600 KC the term radio frequency (RF) is no longer used but instead the term **high frequency** is employed. This covers roughly the frequency band from 1600 KC to 30,000 KC. This band of frequencies covers a wide range of uses such as amateur transmission, ship radio, mobile, police, experimental, international broadcasting, government, aeronautical, etc.

Above 30,000 KC on up to an indefinite point in the frequency spectrum the term **ultra high frequency** is employed. This band of frequencies is employed for a wide range of uses such as government, television, frequency modulation, experimental, etc. We do not yet know the upper limit of the useful frequency spectrum in what is termed as the very high frequency or super high frequency band. Experimental work is constantly going on in these higher frequencies. The useful range of frequencies at



Interior of Westinghouse transmitter KYW, showing one of the control boards.

present is from about 20 cycles on up to the astounding value of 1,000,000 kilocycles.

As we get higher and higher into the frequency spectrum, the numbers get larger and larger even if we use the abbreviated kilocycle form. To avoid the use of these large numbers a still shorter abbreviated form is used. The frequency may then be referred to in terms of millions of cycles. The word **megacycle** (MC) is descriptive of this, meaning 1,000,000 cycles. Thus 1,000,000 cycles is equal to 1 megacycle. 1,875,000 cycles is equal to 1.875 megacycles and 30,000,000 cycles is equal to 30 megacycles.

An easy way to convert cycles to megacycles is to multiply the value in cycles by .000,001. Thus 49,000,000 cycles times .000,001 equals 49 megacycles. To convert megacycles to cycles multiply the value in megacycles by 1,000,000, for example 28 megacycles times 1,000,000 equals 28,000,000 cycles. Occasionally it may be desirable to convert kilocycles to megacycles or vice-versa. To change kilocycles to megacycles multiply by .001 and to change megacycles to kilocycles multiply by 1000. For example consider a broadcast station transmitting on a frequency of 700,000 cycles. Its frequency in KC is 700 and in MC it is .7—this you can prove by carrying out the multiplication.

HOW AF IS CHANGED TO RF

In the foregoing it has been shown that the original AF (audible or sound frequencies) must in effect be changed to a higher frequency if the signals are to reach out to any great distance. Also it has been shown that the workable frequency limit reaches on up into the ultra high frequencies. You should also realize that this is not the limit of usefulness of the frequency spectrum because research may overnight find ways and means of going on beyond the present practical limit, which after all is a very vague and indefinite point in the spectrum.

You may wonder how these higher frequencies are generated. You will remember that it was stated that the AF was generated by audible sounds (air waves) acting on a microphone which in turn translated these sound variations into equivalent electrical variations. In the case of the higher frequencies we cannot very well create original air waves and cause them to act on electrical devices to generate equivalent electrical impulses because of mechanical limitations and for other complex electrical reasons. This problem is overcome by use of a **quartz crystal,** tuning circuits and vacuum tubes, all of which will receive detailed explanations in other lessons. A brief description of these subjects will, however, be included in this lesson.

The next step in the process of getting the original AF signals radiated as a radio or magnetic wave, is to change them into high frequency signals. This must be done in such a way that the original signals are not destroyed. **The change is made by causing the AF to ride on or be superimposed on the higher frequency.** This higher frequency is called the **carrier frequency** because it carries the AF along on it. The higher frequency is of course reversing back and forth very fast since it has many times more cycles per second than

MBS Photo

Remote pick-up transmission being made by Bob Elson of WGN and Tony Wakeman of WOL. Signals are "piped" to studio, then amplified and broadcast from station.

does the AF. Yet the AF can be made to ride along on it just the same. This is roughly comparable to an airplane passenger. His plane may be traveling along at 300 miles per hour through the air yet he can walk back and fourth in the plane at the slow rate of 2 or 3 miles per hour. Once the AF is superimposed on the high carrier frequency it may with suitable power be radiated to any point on earth. At the receiver the process is reversed, wherein the carrier frequency is eliminated and the equivalent of the original AF is made to act on the speaker and so reproduce sounds corresponding exactly to the original sounds at the microphone.

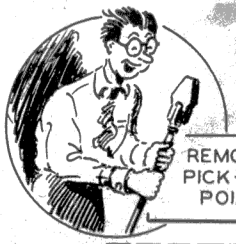
The process wherein all of this is accomplished naturally covers a wide range of subjects which we cannot hope to explain to you in this one lesson. However, now that you have a general idea of how the transmission and reception of signals is accomplished you are ready to proceed with more details of the complete system.

TRANSMITTING THE SIGNAL

A block diagram is an excellent means of showing complex problems in non technical language. Figure 1 is such a diagram showing a complete transmitter and receiver link. The different functions are shown by blocks. There are seven of these in the transmitter system and eight in the receiver. These are called stages. Other systems may employ more or less stages in both the transmitter and receiver system, but the arrangement shown in Fig. 1 is typical of the average installation.

Position 1 of the transmitter system is where the signal first starts. This may be at a night club, race track, prize fight, etc. The sound waves are picked up by the microphone and changed into electrical sound waves. The output of the mike is fed into a small portable amplifier which increases the strength of the AF signal. The output of this in turn feeds the signal to a properly balanced telephone line. This telephone line terminates at the station studio control room indicated by block 2. At this point the signal is again amplified to the desired level, the amount being determined by the control operator. This brings the AF signal to the point where it can be fed directly to the main transmitter. It is at this point where the high frequency enters the picture.

At stage 3 of the transmitter system the quartz crystal previously mentioned comes into play. Such crystals are mined in America and



REMOTE PICK-UP POINT 1

A·F.

STUDIO AND R·F· AMPLIFIER 2

A·F.

MODULATOR STAGE 5

MODULATED CARRIER

MODULATED R·F. AMPLIFIER STAGE 6

CARRIER STRENGTHENED FOR MORE POWER

VERTICAL RADIATOR OR ANTENNA 7

MODULATED SIGNAL RADIATED FROM ANTENNA IN EVERY DIRECTION

CRYSTAL AND TUBE GENERATOR 3

R·F.

R·F. CARRIER AMPLIFIER 4

R·F.

R·F.

RECEIVER SYSTEM

EMPLOYING THE SUPERHETERODYNE CIRCUIT

RADIATED MAGNETIC WAVES

SOUND WAVES

SPEAKER 8

A·F. AMPLIFIER 7

DEMODULATOR OR DETECTOR 6

I·F. AMPLIFIER 5

MIXER 4

R·F. AMPLIFIER 2

RECEIVER ANTENNA 1

LOCAL OSCILLATOR 3

FIG. 1.

Brazil just as many other minerals. They are found in large lumps and are ground down to the desired size by skilled operators. It has been found that such a crystal will control an AC signal within very narrow limits. Every broadcast station in this country is required to employ one of these crystals to maintain the transmitter on its assigned frequency. Different shapes and sizes of crystals are required, depending on the frequency to be controlled. For a given frequency assignment by the FCC the crystal is used in connection with a vacuum tube to accurately generate the carrier frequency. This frequency is amplified or made stronger in stage 4 and it is then ready to be fed to the main transmitter.

Stage 5 is the point in the transmitting system where the AF and carrier frequencies are combined. This is called the **modulator** stage because the AF at this point is made to modulate the carrier frequency. Modulate means to pass from one state to another or to merge. Thus the AF merges with the RF or carrier frequency. Radio men think of the AF as riding along on the RF.

Depending on the amount of power to be radiated into space, the modulated RF signal from stage 5 may go through one or several stages of additional amplification until the signal is built up to the desired level. Stage 6 of the transmitting system in Fig. 1 symbolizes the modulated RF amplification. The high powered modulated RF signal is next fed to stage 7 of the transmitting system, which in modern installations is a lattice net made of steel strips called a **vertical radiator.** From this point the signal is radiated into space as magnetic waves. These waves are symbolized in Fig. 1 by wavy lines between the transmitter and receiver.

RECEIVING THE SIGNAL

At the receiver the process is reversed. The magnetic waves from the transmitter induce voltages in the receiver antenna (stage 1 of the receiver system) corresponding exactly to the RF wave form as radiated by the transmitter antenna. The effect of these voltages is instantly made evident throughout the length of the receiver antenna, regardless of its form. The signal voltages are caused to be fed to stage 2 of the receiver system which is nothing more than an RF amplifier consisting of vacuum tubes and tuned circuits. This builds the relatively weak induced signals of the antenna up to a higher level for further action by the receiver.

The next stage in this particular receiving system is called the mixer or first detector. It has a special function and is included in every superheterodyne type of receiver. There are other types of receivers, but the superheterodyne is most commonly used because of its many advantages over other types. All this will be thoroughly explained to you in later lessons. One main advantage of this type of receiving circuit is the ease with which it selects one signal out of perhaps thousands of signals existing in the antenna system. It is for this main reason that we depict a superheteroyne type of receiving circuit in Fig. 1.

Stage 3 in the receiving system is a low-power vacuum tube gen-

erator called an oscillator. It produces within its own circuit a high frequency voltage which is fed to stage 4 and there combined with the received signal from stage 2. This mixing of the two frequencies in this stage is what permits the receiver to have such a high selectivity factor (selectivity means the ability of a receiver to select one modulated signal frequency out of all others and its ability to maintain this action).

From the output of stage 4 the signal is fed to stage 5, called an Intermediate Amplifier (IF). In this stage the signal is built up to a high level, and by this time it becomes very strong. It is now ready to have its carrier removed because the high carrier frequency has no part in the AF reproduction process. Stage 6 therefore demodulates the signal or removes the RF carrier. This process is also called detection, consequently stage 6 is most often referred to as the detector. In a superheterodyne type of receiver stage 6 would be called a second detector, to distinguish it from stage 4 which is often called the first detector (or mixer). These terms will become thoroughly familiar to you as you make more progress with your studies—remember we are only giving you a general view at this time.

After leaving stage 6 the signal is again rather weak due to the demodulation process. At this time, however, it is the true AF signal just as it started out in stages 1 and 2 of the transmitter process. Stage 7 of the receiver now builds up the AF signal to the desired level and in turn feeds stage 8 which is the speaker or reproducer. The diaphragm of the speaker is caused to vibrate from the action of an intense magnetic field. This vibration of the speaker diaphragm sets in motion actual air waves which reach the ear as sound. Thus a low frequency AF signal may be sent by means of radio and sound waves to any point on the face of the globe.

Besides direct pick-up in the studio and remote pick-up outside, radio signals may be transmitted from electrical transcriptions. At left is a three table record player used on FM (frequency modulation).

Other lessons which are to follow will give you the details of how all of this is accomplished. For the time being this will have to wait while we give you some of the details of sound and radio waves.

Your study of magnetism will assume considerable importance when you think of a radio transmitter continuously discharging 670 horsepower of magnetic energy into empty space (the ether). This energy finds its way to very remote corners of the world. Out of thousands of radio waves constantly crossing and meshing with one another, we can pick out just one with a properly designed radio receiver. Radio waves are constantly pressing out all around and **through** us by the thousands, no matter where we are, unless in a metal vault or steel tunnel, or deep down in a mine. Even in these places, minute quantities of radio energy are present.

STRENGTH OF RADIO WAVES

Our receivers, according to present day standards, can pick up energy from radio waves amounting to three billionths of one millionth of a horsepower and **electrically magnify** (amplify) this energy so that a room or house may be filled with voices or music. Electrical power, which is ordinarily measured in watts, has in this case been converted to horsepower so that you may get some working idea of relative powers from your everyday experiences. Soon you will learn to make these conversions of power, etc., yourself.

In city streets with buildings containing metal structure, the radio energy varies in strength from one locality to another as much as 50 times. Automobile radio receivers automatically compensate for this so evenly and smoothly the listener never suspects that there is any difference in the strength or energy of the carrier wave.

Through the daily papers you are informed that radio programs may originate anywhere, in any building, in a stratosphere balloon, in a parachute while falling, in a dirigible, in an automobile, under a river, in a submarine or elsewhere.

Radio communication depends on the transfer of energy from one point to another. This may be done in a direct manner without changing the form of the energy or by an indirect manner by means of wave motion.

To get a good idea of what is involved in this process consider some of the more common forms of mechanical transmission of energy. In an automobile, the mechanical energy produced by the engine is conducted or transmitted to the driving wheels by means of a clutch, gears, and drive shaft. The circuit over which the energy is transferred comprises the clutch, the gear teeth, the drive shaft, the axles and the axle keys to the wheel hubs. This transfer of mechanical energy is so commonplace that we rarely think of this as a transmission circuit. With hydraulic brakes, energy applied to the brake lever with your foot is transmitted as pressure to the brake drum cylinders.

Steam pipe circuits are used to transmit heat from one place to another. Wires are used to transmit electrical power from generators in a power house to homes for lighting, etc.

HOW SOUND WAVES ACT

All of these are **direct** methods of transmitting energy requiring a **definite confined path** or circuit through which the energy can act. Although these direct methods of energy transfer are used extensively in radio and in other branches of science and industry, there is another way in which energy may be transferred. This method is by means of **wave motion.** The transmission of energy by means of wave motion is quite different from any direct methods. We will therefore start your study of this subject with something with which you are familiar, for example ordinary sound waves.

An example of the direct method of energy transmission is a hollow pipe through which air is made to flow under pressure. The air may be compressed at one end of the pipe by means of a mechanical pump and its pressure will be exerted all the way to the other end of the pipe. By pumping enough air in at one end of a pipe a turbine might be run at the other end, because of the energy which is transferred through air by pressure. Now suppose a **sound wave or vibration** is produced at one end of the pipe. The energy of the sound will travel to the other end of the pipe and can be used as energy with the proper equipment.

Now what is the difference between a steady flow of air through the pipe and the passage of a varying sound wave through it? The answer is a long one which must be analyzed closely. **There is a difference,** and the transmission of radio signals through the ether depends on the **principle** of it, as will be explained later on. In this connection, a steady flow of air may be compared to direct current, and a varying sound wave may be compared to an alternating or oscillating current.

With the passage of a steady air current or flow of air through the pipe, each **molecule** of the air will be traveling at a constant rate of speed toward the other end of the pipe, just as electrons under voltage pressure in a wire will flow along to any place where there is less crowding of the electrons. Air molecules, like electrons, have a tendency to drift to a place where there is less crowding. Their natural constant activity makes them distribute evenly throughout any enclosure and they will flow from a place of high pressure to a place of low pressure, and will continue this movement until the pressure is equal everywhere.

Now note the difference when we are considering a varying air wave. In a sound or air wave the molecules do not move steadily in one direction, but move a short distance in one direction, then reverse and move a short distance in the other direction. In moving in one direction they momentarily crowd others along in the same direction, but they stop and move back because for an instant the crowding is less behind them than in front. Thus an air wave is in effect a continuous movement of small pockets of air pressure from one point to another. It is important to remember that an air wave is continually reversing its motion, and its strength is continually changing just as was described for an AC wave.

Of importance here also is the

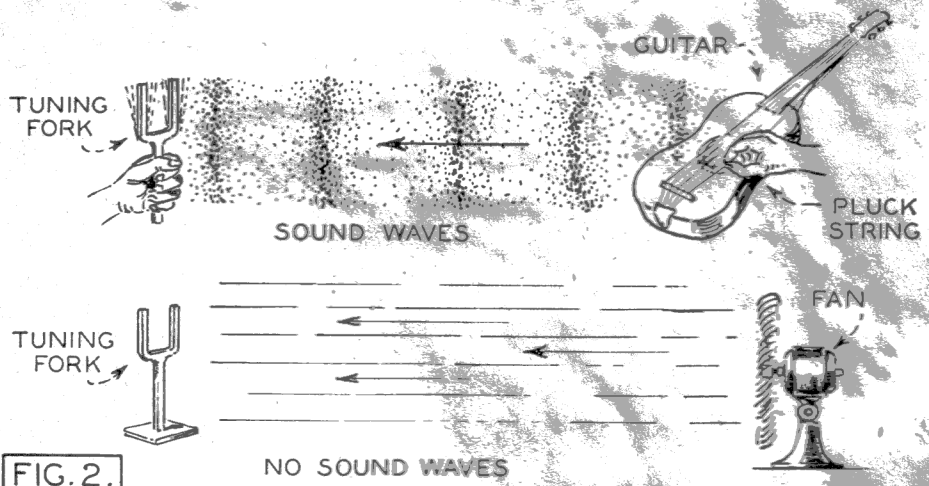


FIG. 2.

This drawing demonstrates how sound waves differ from ordinary air waves, though both travel through the same medium. Sound waves pulse or vibrate at various frequencies, as is shown at the top. Here a guitar string is plucked and sends out sonic vibrations of the same frequency to which the tuning fork is tuned, causing the latter to respond with like vibrations. A direct air wave (lower) having no sound frequency does not actuate the fork in any manner.

fact that the air molecules in producing wave motion move increasingly faster (accelerate), increasingly slower (decelerate) and stop, whereas in a **steady air flow** they move at a **uniform velocity.** No air or sound wave can be produced or travel without this accelerating and decelerating of the air molecules. Every source of sound must, therefore, have these properties in order to cause the air molecules to act in this way.

For any stringed musical instrument, the string moves from its central normal position, to and fro, stopping at each end of its swing or stroke (see Fig. 2). From one end of its swing it travels toward the other at an increasing velocity (accelerates) to the central position and then decelerates until it stops at the other end of its swing. Carefully note that the movements of a clock pendulum are exactly like this. As it swings in this manner, it forces the air molecules to move in the same manner and a wave is produced. In all other instruments, various diaphragms, reeds and valves force the air to move in this manner.

In any air wave the molecules rarely move more than one-fourth of an inch. **The wave motion, however, is transferred to other air molecules, thus the motion is continued until the energy is spent.** A very satisfactory wave may be produced with the molecules moving only one thousandth of an inch one way and then reversing.

Although none of the air molecules move at a constant speed, the wave which they produce does move along at a constant speed under normal conditions. This speed depends on how close the molecules of the air are spaced and the time required for one to react on the next one. For normal air, the speed of sound waves is 1,088 ft. per second. Thus, if a diaphragm, string or reed of a musical instrument starts forward, compressing a small amount of air in front of

it for an instant, these air particles will move out in all directions, and instantaneously compress the air directly surrounding them. This pressure area will be handed on to other air molecules at the rate of 1,088 ft. per second, one after the other just as a wave on water will travel along on its surface.

Now if this accelerating and decelerating influence is started by vibrations in water, the pressure areas in the water will be handed on at the rate of approximately 5,000 ft. per second. For glass, the velocity would be approximately 20,000 ft. per second. For vulcanized rubber, it would be 177 ft. per second. The velocity of sound through these various substances depends on a special quality of each substance, in which we have no interest here. It is well to remember that in **any one** of these substances, the velocity of sound is **constant or the same,** no matter what **kind of sound or tone is produced.**

There is a wide range of sounds or tones. A rapid vibration will cause a high pitched sound (high AF frequency) while a slower vibration will cause a low pitched sound (low AF frequency). If a string or diaphragm reaches its furthest position quite frequently, the sound will be high pitched, but if less frequently, the sound will be lower pitched. Obviously the more often the string swings out, the more frequently the compression areas in the air in front of it will be formed and the closer they will follow one another. How frequently this occurs in a second is quite logically called the **frequency** of the wave.

The term **air wave** has been purposely used because not all air

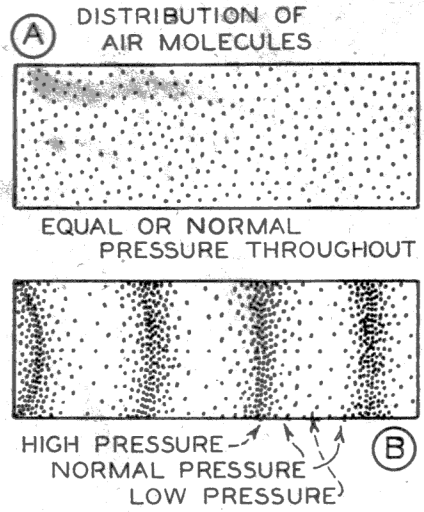


FIG. 3.

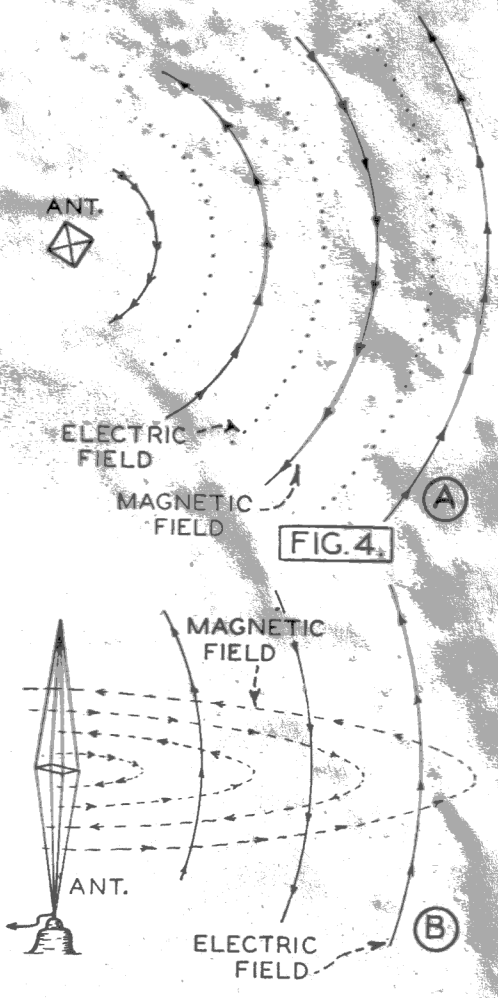
waves will produce the sensation of sound. The term **sound wave** is often carelessly used. Sound is the impression made upon the brain through the nerve connected with the diaphragm of the ear, thus not all air waves are audible because extreme low and high frequency air waves will not produce the sensation of sound on the human ear. Regardless of this technicality the term **sound waves** is in common usage.

As described before, a cycle is one of a complete sequence of events which are repeated over and over again. Thus the movement of a part of a musical instrument causing sound, moving out, reversing and again moving out, is one cycle. If this action is made to occur twenty times a second, twenty cycles have been produced at the end of one second. The first impulse will be 1,088 ft. away and the other impulses will be 54.4 ft. apart, (1,088 divided by 20) all the way back to the source of the sound. At twenty cycles, each impulse (compression area) will move

54.4 ft. before the next one starts. The distance between two successive impulses is called a **wavelength** (54.4 ft. in this case).

If a vibration is made which will make a tone at the same pitch as middle "C" in the musical scale, 256 cycles will be produced. At the end of one second, the first wave will be 1,088 ft. away from the source as before, and the impulses will be 4.24 ft. apart. At 16,000 cycles, the impulses will be approximately .068 ft. or 13/16 of an inch apart.

Between the impulses there are areas or zones where the air pressure is lower than normal. Moreover, the pressure varies throughout a cycle in a gradual manner just as does the voltages of an AC cycle. Ordinary air when not under the influence of an air wave can be represented as in Fig. 3A. When a wave disturbs the air it will appear as in Fig. 3B. Study these two figures very carefully, so as to understand the difference between the two forms of air.



THE ELECTROMAGNETIC WAVE

With the foregoing thoughts in mind you are now ready to consider a magnetic wave. You will find many points of similarity between a sound and a magnetic wave. With this basic knowledge it then becomes easy to understand how a radio wave may be radiated out into space or the ether.

As you already know, **when electrons dynamically move magnetism is produced.** When the electron moves in one direction, accelerating, decelerating, stopping, reversing and accelerating in the opposite direction, the magnetism will increase, reduce and reverse in exact conformity to the electron or AC voltage wave. **As a result an impulse will be sent out into space in much the same manner as described for magnetic lines of force in the previous lesson.**

Just as a **flow of air** at a **constant speed will not** produce **air waves,** a **flow of electrons at a constant speed** will produce **no magnetic waves.** A steady flow of electrons will produce only constant magnetism such as a permanent magnet will produce. But a change in velocity of an electron or group of electrons will produce a wave just

as a change in velocity of a string or diaphragm will produce a sound or air wave.

Because of the nature of magnetism and its relation to space, it is necessary to deal with considerably greater values than for air waves. For example, a magnetic wave travels 903,000 times faster than an air wave—nearly a million times faster. At the higher RF frequencies instead of dealing with vibrations of from 20 to 18,000 per second as for AF, it is necessary to consider frequencies up to several million cycles per second.

When you read in the paper that a certain radio station will transmit on a frequency of 1200 KC it simply means that the electrons in the transmitting antenna are being made to oscillate (travel up and down the antenna) 1,200,000 times per second. Although the electrons may not actually move more than an inch or a centimeter, their velocities and rate of reversal are tremendous.

VELOCITY OF RADIO WAVES

The magnetic waves emanating from a radio antenna consist of expanding circular lines of force **pressing out into space** at a velocity of 186,000 miles per second, which is equal to 299,820,000 or approximately 300,000,000 meters per second (one meter equals 3.28 ft. approximately). The latter figure is close enough for all practical purposes. For the example of a 1200 KC frequency in one second 1,200,000 cycles occur. The first impulse travels at the rate of 300,000,000 meters. The second and successive impulses are 250 meters or 820 ft. (300,000,000 the velocity divided by 1,200,000 the frequency) apart.

Instead of **pressure areas** as for air, there are **force areas** with the magnetic lines of force extended first in one direction, then zero (when the electrons stop) and then the magnetic lines of force extend their force in the other direction. A drawing has been made to picture this wave in Figs. 4A and 4B.

A modern vertical transmitting antenna has been chosen for this drawing and the top and side views are shown. **Although radiation of magnetic waves takes place all around the antenna,** only sections of the wave to the right of the antenna are shown.

From your previous knowledge of the electric field, you know that a concentration or accumulation of electrons will form an electric field and this is indicated in both these drawings.

If you were above the vertical antenna looking down on it and if you could see the magnetic and electric lines of force or waves as they were radiated from the antenna, they would appear somewhat as in Fig. 4A. Please understand, however, that this can only be a symbolic view because it would be impossible to show all the magnetic and electric lines of force on a drawing. The circular lines with arrow heads represent magnetic waves which are being radiated out from the antenna in circles. The dotted circular lines represent electric lines of force. These cannot be shown with length because you are looking down on the antenna in Fig. 4A. Thus it is seen that the electric lines of force are in parallel to the radiator which is the same thing as saying the electric and magnetic lines of force are at **right angles** to one another. Fig. 4B shows a side view of the antenna or radiator. Note this is a view in a different plane. In this case both the magnetic and electric lines of force can be shown to better advantage. Note that the mag-

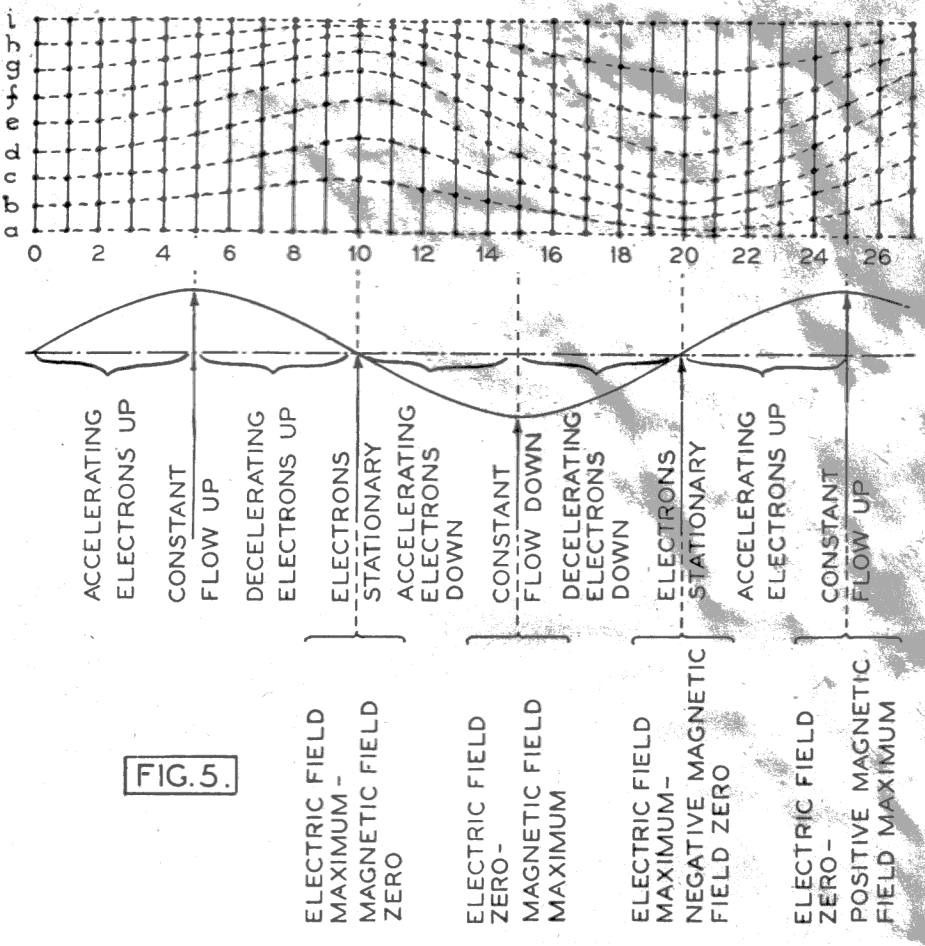

0 2 4 6 8 10 12 14 16 18 20 22 24 26
ACCELERATING ELECTRONS UP
CONSTANT FLOW UP
DECELERATING ELECTRONS UP
ELECTRONS STATIONARY
ACCELERATING ELECTRONS DOWN
CONSTANT FLOW DOWN
DECELERATING ELECTRONS DOWN
ELECTRONS STATIONARY
ACCELERATING ELECTRONS UP
CONSTANT FLOW UP
ELECTRIC FIELD MAXIMUM - MAGNETIC FIELD ZERO
ELECTRIC FIELD ZERO - MAGNETIC FIELD MAXIMUM
ELECTRIC FIELD MAXIMUM - NEGATIVE MAGNETIC FIELD ZERO
ELECTRIC FIELD ZERO - POSITIVE MAGNETIC FIELD MAXIMUM

FIG. 5.

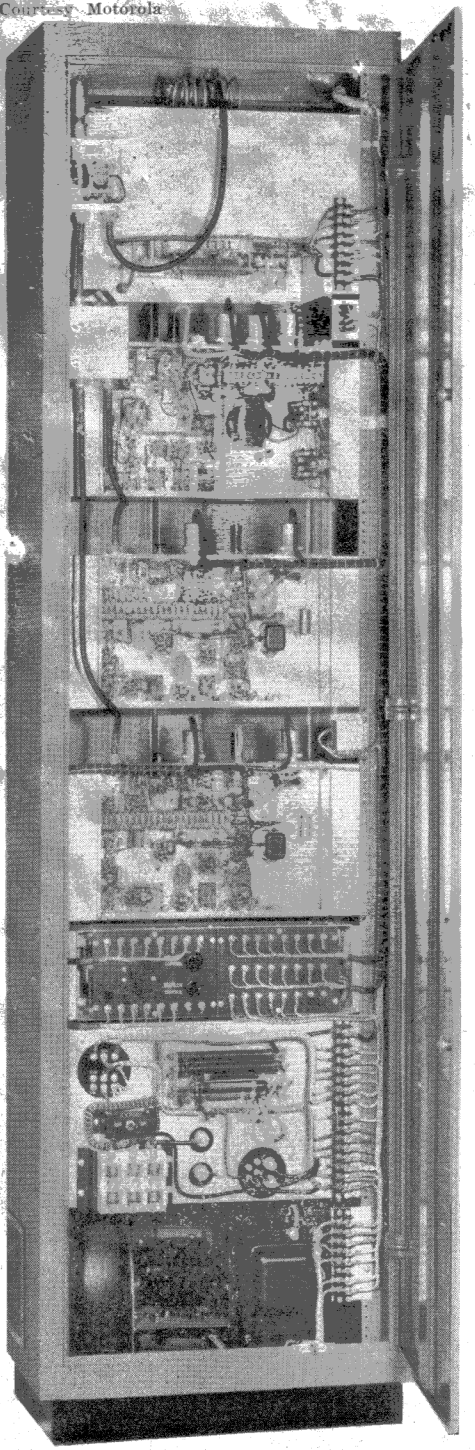
netic lines of force (those with successive dashes) are in circular waves, whereas the electric lines of force are shown as vertical waves with a side view to permit the showing of length. This is just reverse for the conditions in Fig. 4A. Fig. 4 will be referred to again later on with a more detailed explanation.

For your next consideration refer to Fig. 5. In this we have attempted to show exactly what happens to the electrons in an antenna when an oscillating or high frequency current is flowing. The actual distribution of electrons in the antenna are shown for twenty-seven different equally divided time intervals. Twenty of them represent one cycle.

It is extremely difficult to show the distribution of electrons at different time intervals in only one wire or conductor. Therefore, in Fig. 5, each vertical line (numbered from 1 to 27) represents the **same antenna wire.** The only difference between one vertical line and its neighbor is the relative electron distribution **per unit of time.** This drawing is in accord with the AC principles which you studied in the second lesson. To refresh your memory refer to that section of the second lesson dealing with alternating current.

Referring again to Fig. 5, each of

Courtesy Motorola



the dots represents individual electrons. These are lettered A to I inclusive. Those dots along the zero vertical line represent the position of the electrons before they are disturbed by the action of the transmitter. That is, they are evenly distributed. However, the instant electrical force is applied to the antenna circuit, the electrons start moving from atom to atom. At vertical line No. 1 you will note that their relative position is slightly different from the zero position. Likewise, at lines 2, 3, 4, etc. the electrons have assumed new positions. Remember that all of this is occurring in the same wire or radiator and that the nine dots in each vertical line represent the same electron. This one electron being symbolic of all the electrons in dynamic motion in the antenna. The only difference in the dots is that we have shown them in new positions on each vertical line. By drawing several such lines, we in effect stop the motion, and view the path of motion of all of the electrons in relation to different intervals of time.

The dotted lines between the electrons represent the path over which the effect of electron motion is exerted. This, as you can see, is comparable to the effect of wave motion on a body of water. You therefore see that this movement, in effect, creates a wavy up and down motion as the result of electron movement under the pressure of an AC voltage. Now if you will remember that a moving electron which moves in this way also creates a similarly moving magnetic field, you will immediately see how it is possible for a radio or magnetic wave to be created and radiated into space.

Michigan State Police FM transmitter of 250 to 400 watts. Two receivers are also on the same rack in this compact unit.

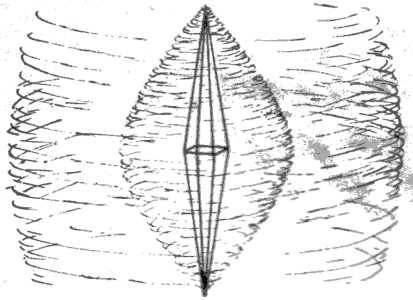


FIG. 6.

Note that from zero to 5 (¼ cycle) all of the electrons in the antenna, except those at the extreme ends, are moving upward. They are increasing their speed of motion (accelerating) up to point 5, and at this point only they are all moving at a constant rate of speed. (Contrast this with the description of Fig. 12 of lesson ND-2). Then still moving up, they are slowing down (decelerating) to point 10 (½ cycle) where they are all stationary. During the time which has elapsed between time intervals zero to 10, a magnetic impulse has been radiated into space in the form of a ring as shown by the magnetic rings in Fig. 4B. At time interval No. 10, this action stops and because most of the electrons are crowded at the top of the antenna, a maximum electric field with lines of force reaching from the top to the bottom of the antenna is formed. These are shown as vertical curved lines in Fig. 4B.

When the current in the antenna is constantly reversing many thousands or millions of times per second, you must realize that this action is occurring very, very fast.

After the electrons reach the time interval corresponding to No. 10, they immediately start moving in the other direction—or, in other words, a reversal takes place. The electrons then start moving down the antenna and gain speed until point 15 is reached. At this point they are again moving most rapidly producing maximum magnetism, but since they are equally distributed at 15, no external electrostatic field exists. The word external is used here because as you have already learned the electric field is always associated with the electron. Just as for a wire carrying no current, the individual electrons in this case simply exert their forces within individual atoms where they have no external effects except that this condition helps give the conductor the characteristics by which it is known. When an electron is part of an atom or molecule its charge is confined to that atom or molecule, as it is neutralized by the equal positive charge when electrically in balance. An external electric field immediately becomes apparent only when the electron is separated from the atom.

With the foregoing explanation in mind Fig. 4 can be better understood. Note these two figures show both the magnetic and electric lines of force expanded out in all directions. In Fig. 4B, the magnetic lines are in the form of arcs or circles successively reversing their directions as indicated by arrowheads. The electric lines of force on the other hand in Fig. 4A, are simply dots because they are at right angles to the magnetic lines and only a cut-away view of the ends can be shown as already mentioned.

In Fig. 4B, the magnetic lines are shown dotted and the electric field lines are shown solid. Note that all lines of force in both Figs. 4A and 4B, indicate the **maximum points of magnetic and electric field** energy and that the maximum points for magnetic force are midway between those for the electric force. When the magnetic force is maximum, there is no electric field force and when the electric field force is maximum there is no magnetism.

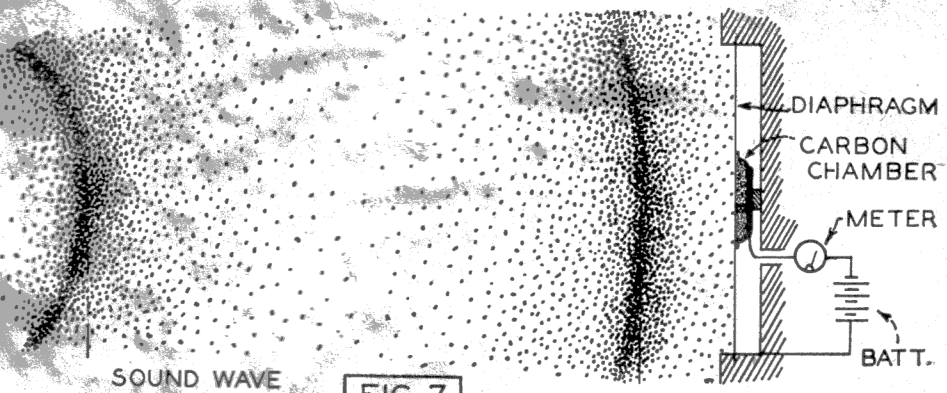


FIG. 7.

While there is only one plane of rings or circles shown for magnetism in Fig. 4 remember that actually there are an infinite number of them all about the antenna as symbolized in Fig. 6. This would be true for each impulse which is sent out by the antenna.

You will remember that moving magnetic lines of force will induce a voltage in any wire or conductor through which they pass or across which they sweep. Thus when a wave such as that described for Fig. 4 passes through a receiving antenna, **a very small voltage** is induced in it, and by proper receiving equipment, this **minute voltage** may be made to control **any amount of power** for the operation of the receiver speaker. The foregoing brief description is the way in which all radio signals are transmitted through the ether from the transmitter to the receiver.

HOW SOUND ENERGY IS CONVERTED TO ELECTRICITY

To return to the sound wave, you will want to know more about how it may be converted into electrical energy so that this in turn may be converted into magnetism for radio transmission.

The various **areas of pressure** and **rarefied air** in an air wave will move small flexible objects in their path, as for instance, a thin microphone diaphragm. The less weight such objects have, the more freely they will move. There is very little energy in an air wave, and the less weight an object has the less its inertia or tendency to remain in position. You will recognize this as an everyday experience. The heavier the object, the more difficult it is to set it in motion and also the more difficult it is to stop after it has gained momentum. Obviously, to convert variations of air pressure into equivalent variations of magnetism all that is needed is to convert the air variations to **current flow variations,** and then make this current flow through a coil of wire which in turn will produce the magnetism.

THE MICROPHONE

Air waves strike the diaphragm of the microphone and cause its moving element to vibrate, following exactly the characteristics of a sound wave. A carbon microphone used for radio purposes has a diaphragm about 2½ inches in diameter. This is made of steel or **duralumin**—an alloy of steel and aluminum having only about one-third the weight of steel. It is quite thin and vibrates in front of a cup of granulated carbon. A diagram of this type of microphone is shown in simplified form in Fig. 7.

The variations in pressure in an

air wave may be indicated as in Fig. 8. In this figure, we have simply plotted the various degrees of pressure of the air for units of time. We can measure one cycle or a group of cycles forming a wave, by using units of length or by using units of time. The horizontal line in Fig. 8 represents the normal or fixed pressure of the air and the representation of the wave (heavy line) shows the manner of increase of air pressure above normal, then return to normal, and then immediately going as much below normal. Other cycles are similar to this one.

You have already learned the definition of direct current (DC) and also what determines the amount of its flow. With a certain amount of resistance in a circuit, a definite current will flow with a definite voltage applied. If the **resistance is increased,** the **current will reduce,** or if the **resistance is decreased the current will increase.** By using a microphone, air waves as in Fig. 7 can be made to vary **the resistance** of a **direct current circuit** with application of the proper apparatus. This type of current flow is called **pulsating**—the current flows in pulses according to the variations of the sound wave. You will learn much more about this type of current flow when you take up the study of vacuum tubes.

As the pressure area of the air

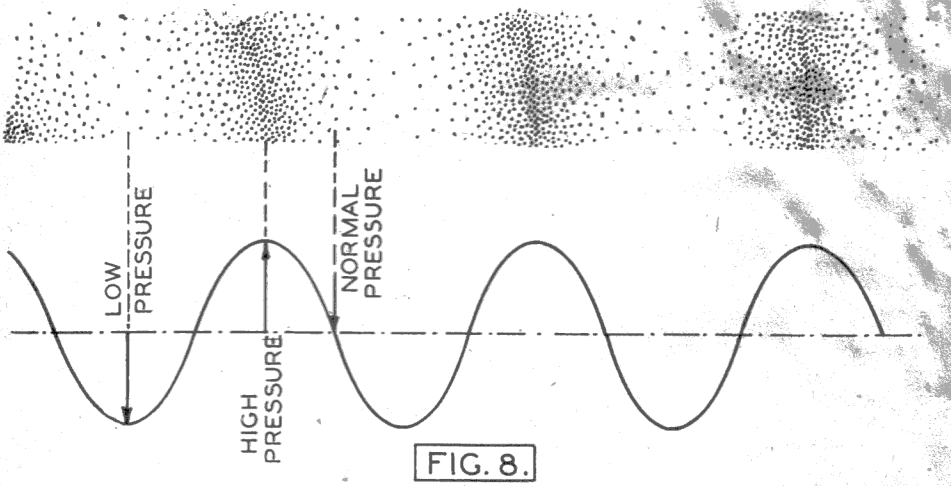


FIG. 8.

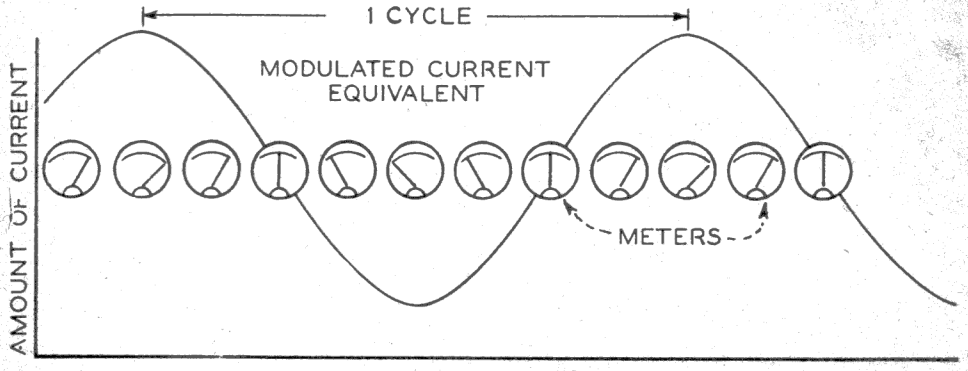


FIG. 9.

wave in Fig. 7 strikes the diaphragm, it is bent in. Immediately in back of it is a cup filled with carbon granules. Pressure on these by the diaphragm will allow more current to flow (decreases the resistance) through the circuit in which it is placed. In effect the carbon cup is a **variable resistance.** When an area of air at lower pressure reaches the diphragm it will bend out and allow the carbon granules to separate (increases the resistance, reducing the current flow through the circuit). This type of varying current flow is shown in Fig. 9. Note that the wave in Fig. 8 is exactly like the one in Fig. 9. One represents the characteristic variations of pressure of an air wave, and the other represents variations of direct current. The round objects in this figure are electrical meters, and serve to show the relative value of the current at different time intervals. The extreme position to the right, on each meter, represents the maximum value of current. The center position of each meter represents zero current. The meter needle passes over a graduated scale and the value of the current is read according to the position of the meter needle with respect to the graduated scale. You will study the fundamentals of electrical meters later on.

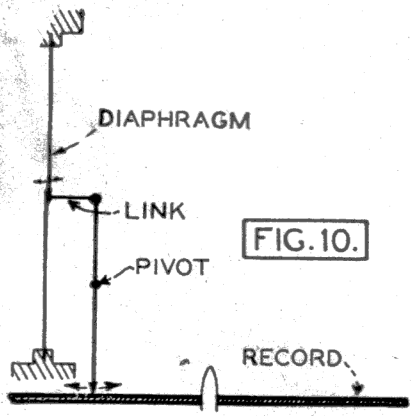


FIG. 10.

MODULATION

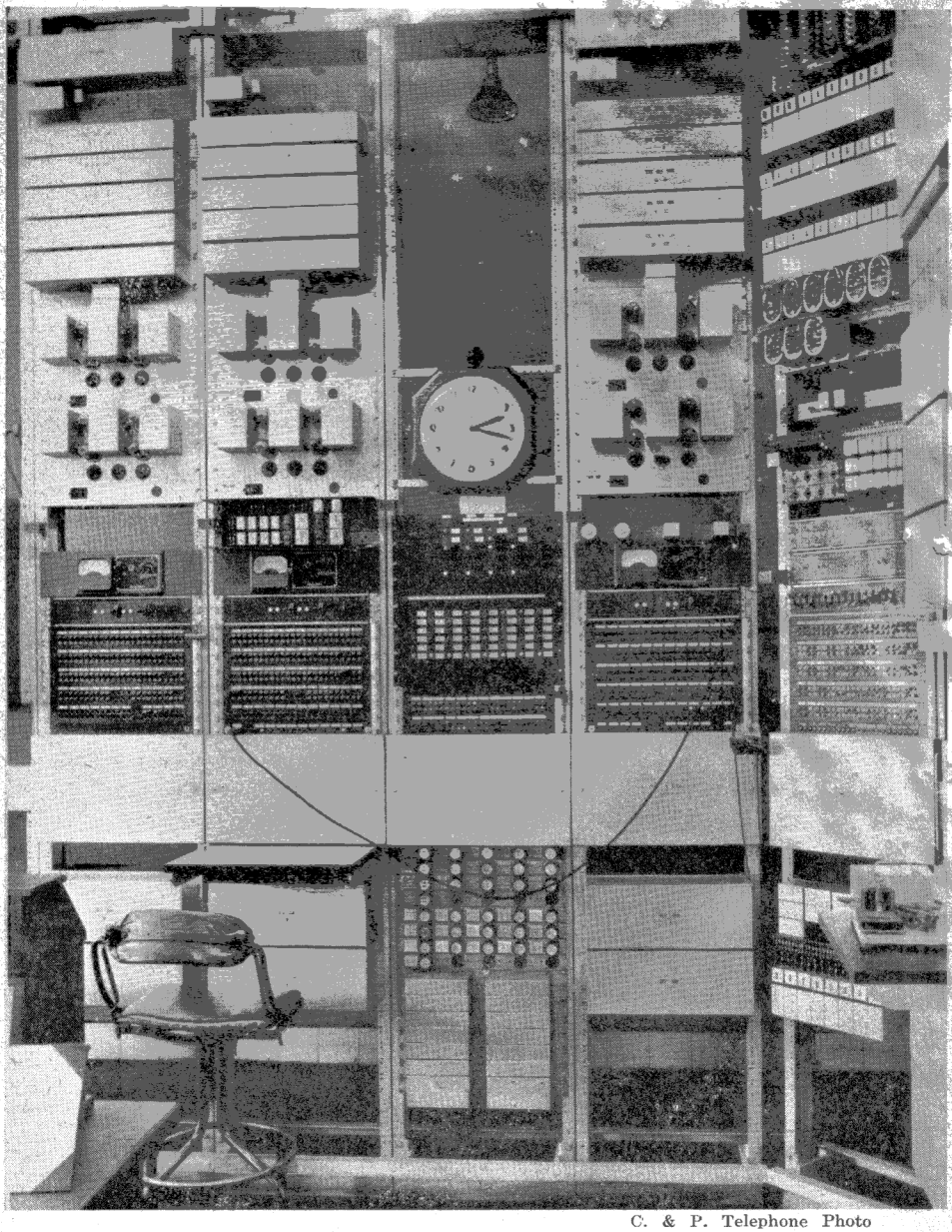
The wave form in Fig. 8 is called an air or sound wave **equivalent** or it may be referred to as a **voice current.** This process whereby a direct current is made to vary in accordance with a wave, is called **modulation.**

Here is another interesting fact. If the diaphragm of Fig. 7 were arranged as in Fig. 10, it could be made to cut a groove in a wax disc from which a phonograph record could be made. The groove is commonly referred to as a **sound track.** Now when the record is used for reproduction it forces a needle to move as the track is traversed. This will move the diphragm of the unit on the record and reproduce the original electrical wave.

This sound wave equivalent is **electrically magnified** (amplified) and radiated into space by means of the radio wave as described in the foregoing part of this lesson. The continuous radio wave acts somewhat like a wire which is carrying current. It simply carries through space the sound equivalent from the transmitter to the receiver.

When the signal reaches the receiving antenna, as was explained before, a voltage is induced in it. This is impressed on apparatus in the receiver, which amplifies it as much as several million times. At the receiver antenna, the **magnetic energy** of the wave is converted into **electrical energy** and this is again **converted into sound waves** at the speaker.

In a preceding lesson it was mentioned that the voltage induced in a conductor depends on the speed of the magnetic field which sweeps through the conductor. Now it must be remembered that any varying magnetic field will induce a voltage in any conductor, even



C. & P. Telephone Photo

Set-up of the Chesapeake and Potomac Telephone Company, showing switchboard through which radio programs are interconnected between stations of chains, remote pick-up and transmitter tie-in.

though it varies at only 60 cycles, as for ordinary house lighting systems. The magnetic field variations accompanying this very low frequency without an iron path to carry them and a coil to concentrate them would be so small as to be unmeasurable. If oscillations of electrons in the wires are increased to say 3,000 cycles per second, very

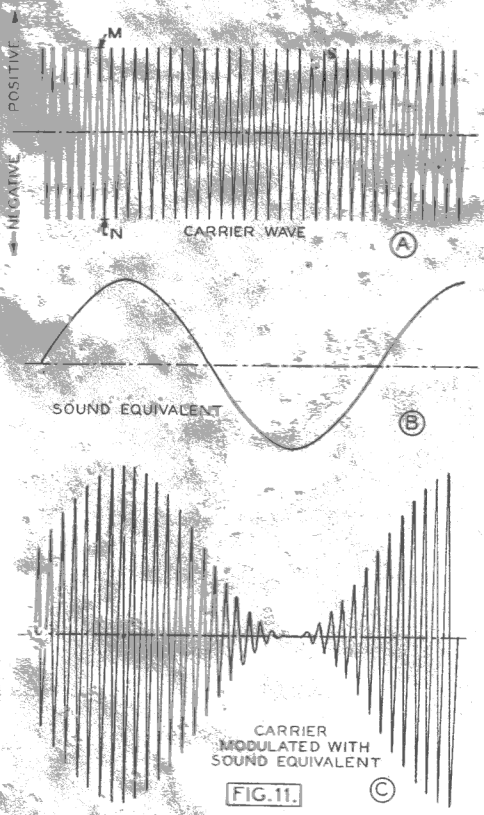


FIG. 11.

much more energy will be radiated. In this connection, a clock pendulum in the action of swinging to and fro causes air waves at one or two cycles (average), but the intensity is so low that they cannot be measured or will not cause response in the ear as sound. When a violin string vibrates at from 30 to 10,000 times per second, air waves will be produced to which your ears are sensitive. At a sufficient distance, however, no sound will be heard as the energy dies (dissipates itself) very rapidly as it progresses out from its source. Thus for a wire carrying electrons which are reversing at 3,000 cycles, the magnetic energy radiated may be strong enough to induce a measurable voltage in a conductor at 25 to 50 feet, but beyond this, its existence would not even be suspected. Just as for sound waves, the current can be made stronger and the signal will travel farther, but there is a much better way than this to accomplish the desired results.

If an electron current in a sufficiently long wire or conductor (transmitting antenna) is made to oscillate at 1,000,000 cycles, the rate at which the magnetic waves will pass through other conductors (receiving antennas) will be so great that a measurable voltage will be produced thousands of miles away. At 30,000,000 cycles, the rate of change of the magnetic field is so great that with little more power than is required for an electric clock (about 5 watts), satisfactory signals may be sent to any point on the earth.

Because all sounds are limited to air waves ranging in frequency from 20 to 18,000 cycles, magnetic equivalents of this could not travel more than a few feet through space and still maintain enough energy to be useful. That is why a **high frequency carrier** wave must be used for radio transmission. Where there is a wire line such as is used for a telephone circuit, the energy is not radiated into space as magnetism, but is confined to the electrical circuit in the form of a varying current flow.

A graphical representation of the variation of a magnetic wave which has been described as the carrier wave is given in Fig. 11A. Note that the amount or intensity of magnetism varies rapidly as time goes on, but it reaches the same positive maximum value, M, for each cycle and the same minimum value, N, for each cycle. This denotes that a constant average amount of energy is in the wave at all times. In Fig. 11B the electrical equivalent of a low frequency sound wave is shown.

Suppose the carrier wave of Fig. 11A is made to increase and de-

crease its **average** amount of energy to conform with the low frequency wave in Fig. 11B. It would then appear as in C of Fig. 11. Now this will **induce a voltage** in the **receiving antenna** having these **exact characteristics.** This voltage will then be amplified and the carrier wave energy will be converted into the sound equivalent of Fig. 11B again. This will be amplified again and a speaker may be then operated with this current thus reproducing the original sound which may have occurred thousands of miles away.

COMPARATIVE SPEED OF SOUND AND MAGNETIC WAVES

To get a good idea of the relative speed of sound and magnetic waves, if the speaker or artist at the studio is three feet from the microphone and the listener is seven feet from his loudspeaker, it will take longer for the sound to travel to the microphone and from the speaker of the radio to the listener's ear, than it will take the radio wave to travel from the transmitter to the receiver, even if they are separated by 1,700 miles. This is because sound waves trav so much slower than radio waves.

A comparison of a telephone circuit and that of a radio circuit is shown in Fig. 12. At the left is shown the microphones and at the right is shown the speakers or reproducers. In the telephone circuit, **sound variations** are converted to **electrical variations,** and these electrical variations in a direct current circuit are made to pass through a coil wound on an iron core. The latter is mounted directly behind a thin steel diaphragm. These current variations are accompanied by similar magnetic variations which cause the steel diaphragm to be attracted by various amounts.

Thus a sound wave is produced at the receiving end, which is exactly like the original one except for the natural imperfections of the mechanical or electrical system.

The radio transmission circuit consists of a microphone which is not unlike the telephone type, but is made with more precision and produces a more exact electrical equivalent of the sound wave. Omitting the construction details of the transmitter, this sound equivalent is made to compress and ex-

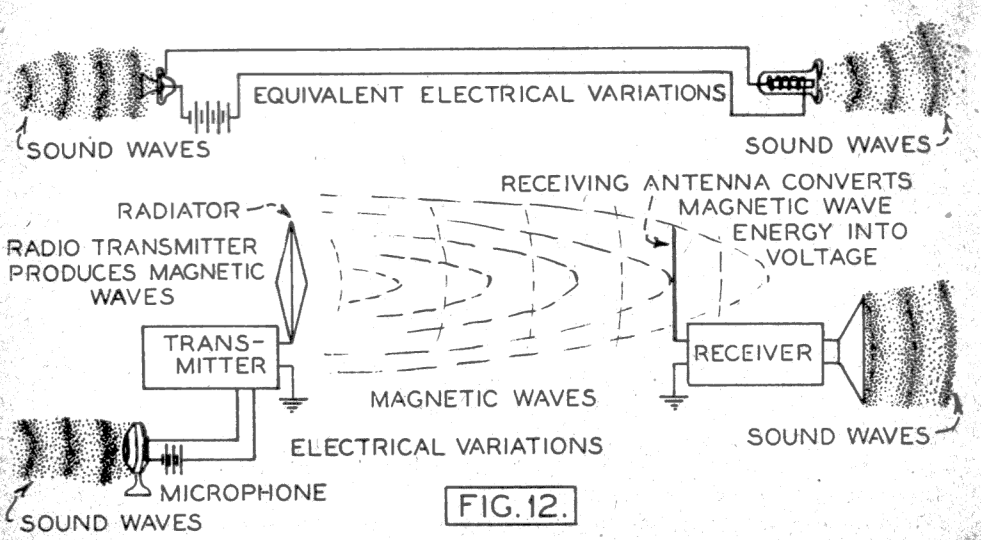
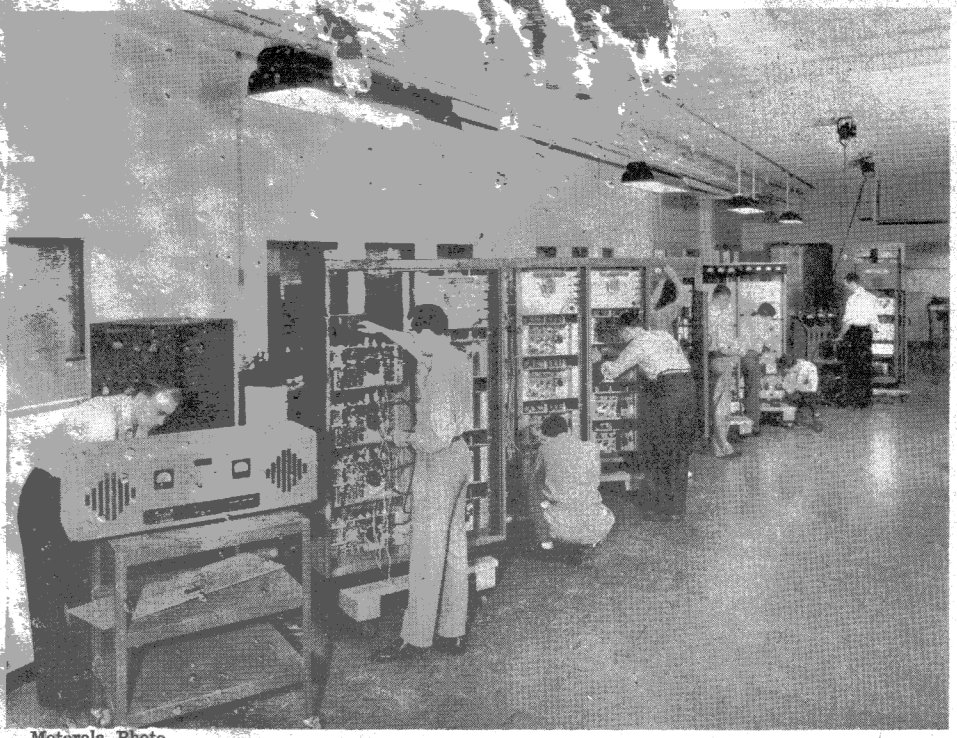


FIG. 12.



Motorola Photo

Transmitter testing station of the Motorola Company. Control panel is at far left.

pand the average energy of the carrier wave which is being constantly radiated into space. The receiver then converts this **modulated carrier energy** into the sound equivalent and the speaker reproduces the original sound. See the lower part of Fig. 12.

To effectively perform its function, a radio receiver must be able to select one magnetic wave out of the thousands which are almost constantly being radiated, change the high frequency energy to usable energy at the original sound or modulation frequencies, and reproduce the sound at a full volume, while keeping it like the original.

For accomplishing the first thing, that of selecting any wave from a large number, the receiver must have a **tuning system** which you will study in considerable detail in later lessons. In order that the weakest signals may be effectively converted into usable sound equivalents, **amplification** must be used before, after, or during the selection of the wave, called tuning. This is accomplished by using vacuum tubes. A special circuit called the **detector** circuit removes the voice current wave from the carrier wave. At this point the voice current equivalent is far too weak to be converted into sound, so further amplification must be accomplished. The section of the receiver which does this is called the **audio amplifier,** as mentioned earlier.

Many radio principles have been covered in this **general** discussion of transmission and reception of radio signals. In this short space it has been impossible to supply all details; however, it has given you a brief insight into this remarkable wonder. The technical details will be supplied in later lessons.

These questions are designed to test your knowledge of this lesson. Read them over first to see if you can answer them. If you feel confident that you can, then write out your answers, numbering them to correspond to the questions. If you are not confident that you can answer the questions, re-study the lesson one or more times before writing out your answer. Be sure to answer every question, for if you fail to answer a question, it will reduce your grade on this lesson. When all questions have been answered, mail them to us for grading.

Questions

No. 1 How must the molecules of the air move in order to produce a sound or air wave?

No. 2 What becomes of the energy of a dynamically moving electron when it is rapidly brought to rest?

No. 3 Describe the two fields of force which form a radio wave.

No. 4 In Fig. 5, explain briefly why there is no magnetism at point 10 and why there is no electric field at point 15.

No. 5 Describe a voice or audio current.

No. 6 Why cannot the magnetism resulting from an audio current be transmitted to great distances without a high frequency carrier wave?

No. 7 In what way does an electro-magnetic wave act on a receiving antena?

No. 8 Give the value of 489,000 cycles in kilocycles and in megacycles.

No. 9 What part of a receiving circuit removes the high frequency carrier and leaves only the voice current energy to be amplified.

No. 10 Why must an audio amplifier be used in a receiver?